Participatory Sensing for Emergency Communication via MANET

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***Abstract-* Most large-scale disasters are characterized by breakdown of essential communication systems. The failure of telecommunication system reduces the pace of emergency response and relief efforts. The paper is confined mainly on how communication can be carried even when a cellular network is down. The proposed system designs a participatory system for emergency communication. The existing participatory sensing systems have not addressed the issues arising when an area is hit with a disaster. By creating mobile ad hoc network of smart phones, it would be possible to allow messages requesting help to pass between phones until they are intercepted by a node which can directly connect to the cellular network or internet. An algorithm for routing the message in such a network is presented. It also showcases an android application called Android app for Emergency Communication (AEC) which would perform this task.**

***Index Terms-* Participatory Sensing, Android, Smartphone, MANET**

I. Introduction

Every year world is hit by large scale disasters like earthquake, flood, landslide, tsunami etc. In addition to these natural calamities, there are man-made disasters like bomb-shelling, nuclear explosion, etc. Telecommunication failure is one of the major impacts of such disasters. The loss of communication systems makes the rescue operation tedious. This reduces the pace of rescue operations which may lead to death of people. The people in the disaster remains isolated from the outside world due to this very reason. Hence, the goal of the project is to develop a system that can provide an effective communication system even when cellular network is down. In [1] and [2] the authors discuss about the causes of failure of communication systems during disaster and they claims the unavailability of communication owe to either physical damage or network traffic overload.

In a post-disaster scenario where cellular communication is down, our system will offer a solution by creating a Mobile Ad hoc Network (MANET) of smartphones. Since we are only making use of the smartphones of the users, there won't be any extra cost adhered. Incorporating participatory sensing technology into such an emergency system will make the entire system more robust and reliable.

Fig 1: Disaster

The paper is structured as follows. Section II presents the existing systems that have addressed the issues regarding emergency communication. Section III introduces the relatively new technology called 'Participatory Sensing'. Section IV gives the architecture of the system. Sections V details the algorithm designed to support the system is obtaining pretty good efficiency. Section VI discusses about the research carried out and briefs about the Android application developed as an initial step to the realization of the proposed system. Finally, conclusions are drawn in section VII.

II. RELATED WORKS

Communication in disconnected ad hoc networks using message relay [5] introduced a new methodology of passing message between groups of mobile hosts, by actively modifying the trajectories to transmit messages. It also discusses two classes of algorithms depending on two different assumptions: (a) the movements of all the nodes in the system are known and (b) the movements of the hosts in the system are not known. Another research by Jan Beutel et al [6] presents Bluetooth Smart Nodes which can store information, compute and communicate using standard wireless interfaces on a limited resource platform. These wireless enabled small devices are capable of interacting in a heterogeneous environment. But, unfortunately, these researches did not considered the limited power processing of mobile nodes. Researchers have explored the possibility of using Bluetooth in the development of a Mobile Ad-Hoc Network (MANET) suitable for transmitting data between

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Symbian OS based Smartphone's. It also present the design of a collaborative application engine by making allowances for the restrictions associated with Bluetooth [7]. It also addresses the issues that be encountered during try to make a bluetooth network of smartphones.

Yao-Nan Lien et al [8] proposed a low cost easy to deploy walkie-talkie communication system based on a MANET P2Pnet of volunteer's laptops. They used Wi-Fi over multi hop for data transfer. The system is designed to support emergency communications in the early hours of a catastrophic natural disaster when external assistance is blocked by the paralyzed transportation system. .It is very useful in the situation when face-to-face communication or wireless links is blocked by the obstacles since our multi-hop system can bypass obstacles easily.

Mesh routers can provide access to external network in a network of mesh clients [12]. While the infrastructure provides connectivity to other net works such as the Internet, Wi-Fi, Wi-MAX, cellular, and sensor networks; the routing capabilities of clients provide improved connectivity and coverage inside the WMN. Multi hopping technology is used to achieve larger connectivity. And also they tried for battery powered routers. Yoshitaka Shibata et al [13] introduced a larger scale distributed disaster information network system based on Mobile Adhoc network (MANET). MANET is used for the access network for residents and volunteers around the disaster area and evacuation places. The evacuated residents and volunteers can flexibly communicate with others though MANET using IP based terminals, wireless IP telephones and Mobile PCs. Some of the wireless mesh network concepts were borrowed into our system.

All the afore-mentioned methodologies and applications for emergency communication were not developed targeting people who are in a traumatic state or who do not know much about the technology. Those applications also don't look into the location tracking of the user. The prime aim of our system is to develop a user-friendly emergency app for such users.

III. PARTICIPATORY SENSING

Participatory Sensing is a new application paradigm that aims to turn personal mobile devices into advanced mobile sensing networks. Here individuals in the general public collect, share and analyze local data. Since this approach was put forward, there have been many participatory sensing systems developed in areas such as environmental monitoring, urban monitoring, and visit monitoring. The prime goal of participatory sensing has been to enhance and evolve existing methodologies by improving quantity, quality and credibility of community gathered data [3].

Incorporating Participatory sensing to an emergency communication should be done with utter caution. The efficiency and reliability of a participatory sensing system largely depends on the number of users that are willing to participate. The more the number of participants, higher will be the efficiency and the reliability of the system. The system should be location-aware so as to aid in tracking the victim. Less power consumption is another desirable feature. Privacy, information fusion and data visualization are other open research problems in this field.

IV. ARCHITECTURE FOR MANET BASED EMERGENCY COMMUNICATION SYSTEM

In times of emergencies, cellular and phone systems are often destroyed or severely damaged, which prevents civilians from communicating with fire, police, or medical services. By creating broadcast, ad hoc networks using smart phones, it is possible to allow messages requesting help to pass between phones until they are intercepted by a phone which has either cellular connection or Internet access available, so that it could forward the messages to emergency services. The basic architecture for the same is shown in the below figure, is capable of conveying emergency messages in the format of text, by creating a self-configurable (MANET).

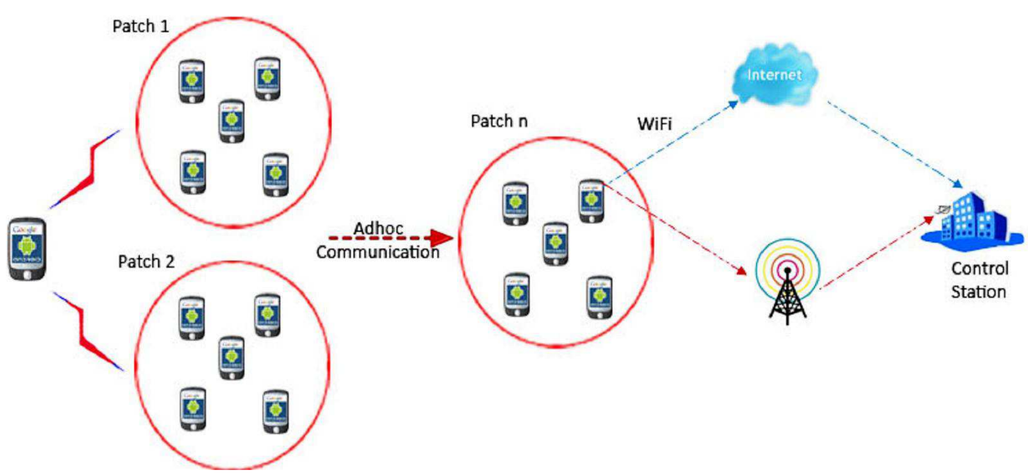

Fig 2: Basic architecture of the proposed system

The system consists of smartphones which forms patches of BT (BlueTooth) node networks. Patches more or less resemble piconets in a scatternet, but vary in the say sense that they needn't overlap each other. But since the nodes are mobile, they might overlap at some point of time, when the exchange of data can occur between the adjacent patches. These nodes will keep on forwarding the data until it is intercepted by a smartphone with cellular connection or internet connection so that the message could be finally send to the actual destination. This destination could be either some emergency service stations or some other mobiles which may be even being pretty far away from the source.

The entire system is viewed as patches. We refer the patch at the end, i.e. one in the cellular range, as 'Patch n' and all other patches as 'Patch i'. We also define a term called 'Patch 0' which includes the origin node, i.e. the sender is said to be in 'Patch 0'. The message flow between these patches is depicted in the following figure.

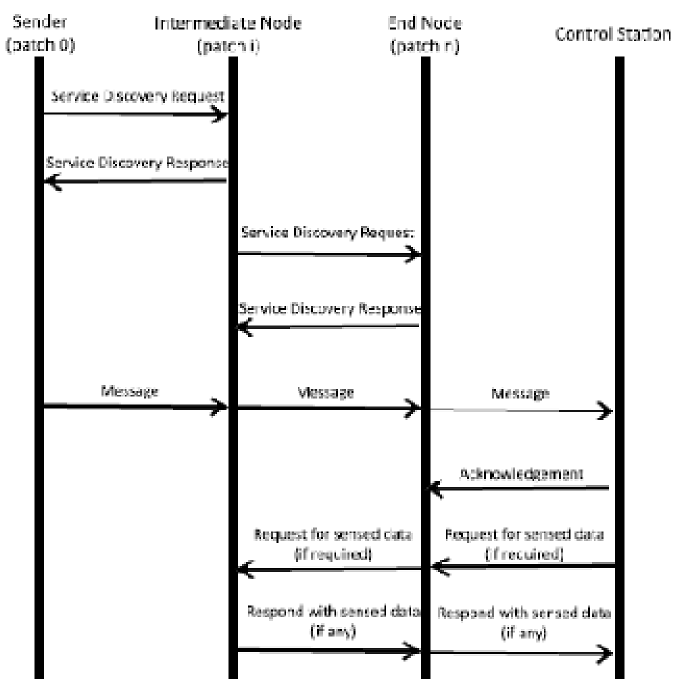

Fig 3: Message Flow

The sender, belonging to patch 0, initiates the communication procedure by sending service discovery request to all the nodes in its communication range, to identify all the nodes with the application installed. All the nodes which recognize this request respond with a service discovery response. At this point, the connection is established between the sender and all the identified nodes. Using participatory sensing would means more chunks of data and this large data should not prevent the successful delivery of message. So as a precaution at first, the sender only sends the help message with the GPS data appended. The intermediate nodes receive this message and they pass it to all the nodes in their vicinity. This procedure continues, until some node belonging to patch n obtains this message and this node will forward this message to the control station. On receiving this, control station could either send emergency responders immediately or could even ask for more sensed data like temperature values, captured images, etc. to study about the disaster-hit area and to determine the effect of the disaster.

V. ALGORITHM USED

Research papers [5] and [6] presented some methods for message passing in ad hoc network. But they never addressed the issue of location awareness and power consumption. In the project, we employ GPS data to track down the location of the user. Considering the emergency situation, the message is send in a broadcast fashion so as the probability of reaching the desired destination is high. But at the same time, the batter drain is prevented by setting a maximum hop count. Once the message reaches the destination, a control message is broadcasted by the destination to turn off the Bluetooth of the other participants.

It is assumed that each of the users have an Android phone in which AEC is installed and is running. The service discovery procedure ensures this condition by authenticating means of 'App Name' and 'App UID'. And only then, it passes the message to the other smartphone.

The algorithm used for routing is given below. The messaged format is also shown below. Considering the distributed nature of the system, the application is carried out in sub-methods which run simultaneously.

Sender Number	Message	GPS Data

Fig 4. Message format

Considering the distributed nature of the system, the application is carried out in sub-methods which are given below.

Initialisation()
Initialise AEC app

- i. *Set flag=1*
- ii. *Set maximum hop.*
- iii. *Get the text message.*

Main()

1. *Begin search for BT node in the vicinity (10 metres)*
2. *Perform service search, to know which nodes have AEC app. Let X_n be the set of all such nodes.*
3. *Broadcast the message to all $x \in X_n$.*

Routing_table_transition()
Repeat this function every 30 seconds

- i. *Generate Device String of nodes within one hop*

```
ii.   Update the routing table
        a. Discard stale routes
        b. If a new path with short hops found,
           replace the route for that destination.

Check_connection()
Repeat this function every 10 seconds
If(Connected)
{       convertMsg();
        if(net.Type==2G || net.Type==3G)
                        sendSms();
        else if(Internet is available)
                        sendEmail();
}
```

VI. EXPERIMENTATION AND RESULTS

The entire project was realized in two phases

1. Mobility Pattern Study at Post-Disaster situations
2. Development of Android App

A. Mobility Pattern Study at Post-Disaster situations

The mobility pattern of participant nodes in a post-disaster situation was studied. But, at first we try to do a simple mathematical analysis of the transfer of data between nodes connected using Bluetooth. The range of Bluetooth is 30 feets, which is approximately 10 metres. This implies that we would need a quite large number of nodes to cover a large region. But, in a real scenario the number of nodes will be relatively small in number. The fact that the nodes are mobile makes our aim realizable. The following analysis tries to claim the same.

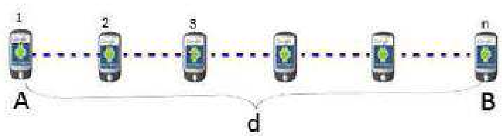

Fig 5: Ideal Case

Let 'n' be the number of total nodes and 'd' be the distance between A and B. Then, the following condition should hold if message should traverse the distance 'd'.

$$d < (n - 1)30\text{feet}$$

If the participant density, M_d is high, the following transmission pattern can achieve the desired result of calling the emergency service by creating an ad hoc network in a circular manner.

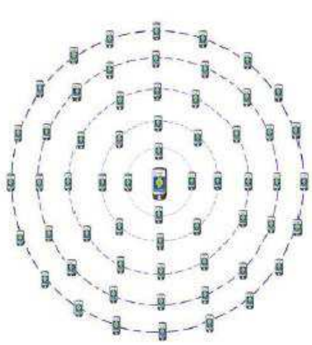

Fig 6: Broadcast transmission

The circular pattern is assumed as the message is transmitted in a broadcast fashion. The following condition should hold each consecutive circle should be in communication range.

Number of nodes in n^{th} circle = 4n

Radius of n^{th} circle = (10*n) metres

The density pattern was studied over a 1km x 1km region of nodes with a maximum speed of 10m/s which justifies the speed of people an after-disaster situation. A matlab program which intakes the mobility parameters was developed and run, with the parameters set as following.

1. Dimension: 1 km x 1 km
2. Minimum Speed: 0 m/s
3. Maximum Speed: 10m/s

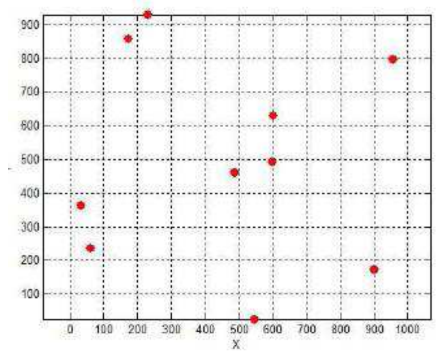

Fig 7: Random positions of nodes for n=10

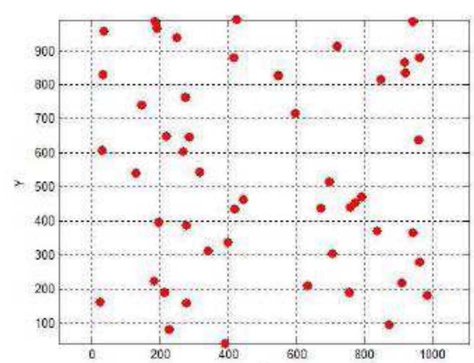

Fig 8: Random positions of nodes for n=50

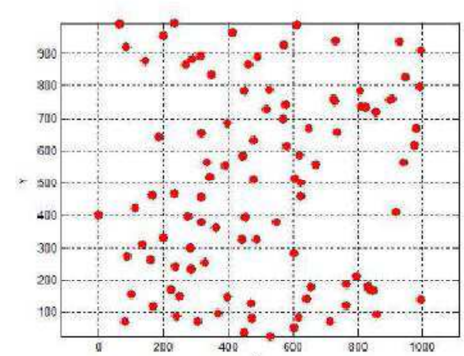

Fig 9: Random positions of nodes for n=100

Clearly, the above graphs indicate that higher the density of the participants, higher is the efficiency of the system as the probability of successful delivery of messages in directly proportional to the number of nodes.

i.e. P(successful message delivery in a given time) α n

P(successful message delivery in a given time) α mobility

The speed vs. time performance was also studied and it was seen that the mean speed of nodes die as the time moves on, i.e. the nodes tend to be stationary when a huge amount of time is passed.

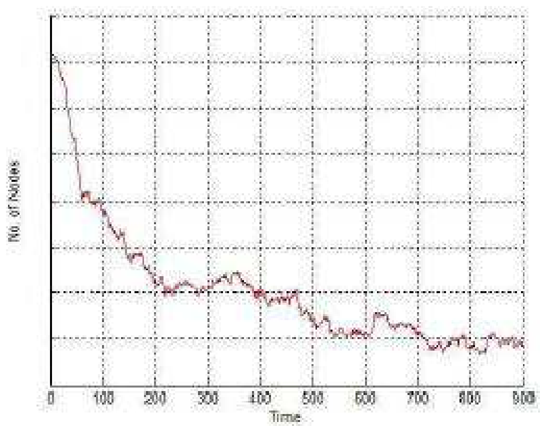

Fig 10: No. of mobile nodes Vs Mobility

From the graph, it could be clearly inferred that a good emergency communication system should try to deliver the message as soon as possible.

B. Android App for Emergency Communication (AEC)

An android app named Android app for Emergency Communication (AEC app) capable of sending message using an ad hoc network of smartphones, using Bluetooth, was developed. Once disaster strikes, the users have to manually switch on the app. The app has an option to send message where the user could himself enter the message. In addition to the emergency numbers like 112 and 911, user could also wish to send the message to their dear ones. This input message will be appended with GPS data and other sensed values like temperature, light, etc. This makes the destination, often a control station, easy to track down the victim and understand the urgency of the situation.

The app developed was successfully tested in a testbed of three HTC Google Nexus Smartphones, which uses Android OS, v2.1 (Eclair). Of them, only one was provided with cellular connection. The A-GPS (Assisted Global Positioning System) was used to get the location of the node which has cellular connection. A localization with this node as reference point can yield the position of the actual victim.

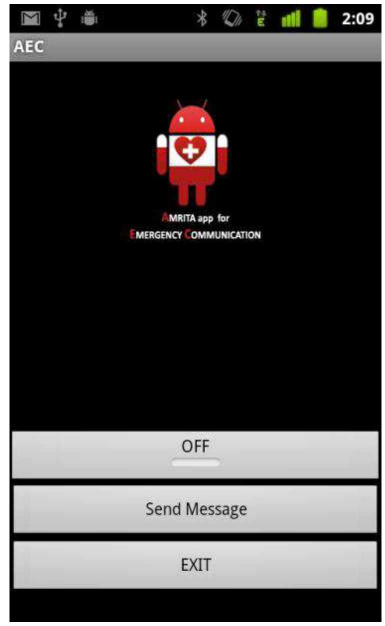

Fig 11: Android App for Emergency Communication

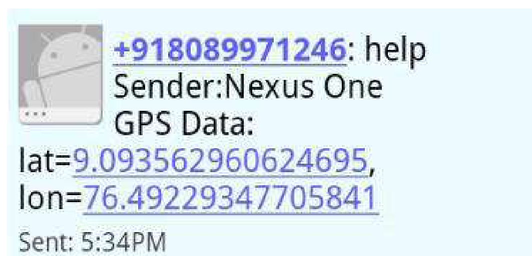

Fig 12: Message received at the destination

VII. CONCLUSION AND FUTURE WORK

Due to various reasons like congestion in the network and damage of communication infrastructures, in a post-disaster scenario the telecommunication will be damaged, which implies that one cannot rely on the cellular communication anymore. Several systems and research papers have addressed the issues associated with this and offer solutions by creating temporary connection for emergency communication. Unfortunately, most of them required extra devices for communication and users should be well adverse with such systems. This project aims to develop a Mobile Ad hoc Network (MANET) based emergency communication system that employed android-based smartphones to create such a network. The app developed would help the users to send messages to emergency services as well as their dear ones.

In future we hope to incorporate voice-to-text conversion in smart phone for the generation of text messages, which can make the system more user-friendly. Information fusion will also be done to make the system more efficient.

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